"Total Eclipse of the Sun, 1900, May 28. Preliminary Account of the Observations made at Ovar, Portugal." By W. H. M. Christie, C.B., M.A., F.R.S., Astronomer Royal, and F. W. Dyson, M.A., Sec. R.A.S. Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received October 18, 1900.

[Plates 2—5.]

I. *General Arrangements.*

An expedition to observe the total solar eclipse of May 28 having been sanctioned by the Admiralty, it was arranged, in concert with the Joint Permanent Eclipse Committee, that the Royal Observatory party should take photographs of the corona on a large scale for structural detail, and on a smaller scale for the coronal streamers, and should also photograph the spectrum of the "flash" and of the corona. The programme thus naturally divided itself into two parts, Mr. Christie, assisted by Mr. Davidson, taking charge of the first part, and Mr. Dyson of the second.

The party are much indebted to the Portuguese Government for the liberal arrangements made for the conveyance of the observers and their instruments in Portugal free of all charge to and from their observing station at Ovar, and for the great assistance rendered in erecting the instruments, and for a daily time-signal from the Lisbon Observatory direct to the observing station.

They are also indebted to Mr. Frank Rawes, of Oporto, for making all arrangements for a suitable observing station at Ovar, and for much thoughtful provision for the comfort and convenience of the observers.

The party further received valuable assistance from Mr. J. J. Atkinson, who went with them from England, and from Mr. Arthur Berry, who joined them in Portugal on May 20; they readily joined in all the work of the expedition, such as the erection of huts, instruments, &c. The party are also indebted to them, and to Mrs. Kennedy and to Mr. Rawes, for assistance in the observations on the day of the eclipse.

Itinerary.—The observing huts and instruments were sent to Southampton on May 8, with the exception of the 16-inch cœlostat mirror, and two boxes of photographic plates which were taken with the observers' personal baggage. The observers left Greenwich on the morning of Friday, May 11, sailing from Southampton by the Royal Mail steamship "Clyde," and reaching Lisbon about noon on May 14. After an interesting visit to the Royal Observatory at Tapada, Lisbon, on May 15, the observers left for Ovar on the evening of May 16, and arrived there on the morning of Thursday, May 17.

They left Ovar for Lisbon on Tuesday evening, May 29, the day after the eclipse, and left for England by the Royal Mail steamship "Magdalena," on Friday, June 1, reaching Southampton on June 4, and Greenwich on June 5. While at Lisbon, the Astronomer Royal had the honour of an audience with His Majesty the King of Portugal.

Station.—The station chosen was at Ovar, in Portugal, near the extreme westerly point of the line of totality in Europe, having the advantage of the longest totality.

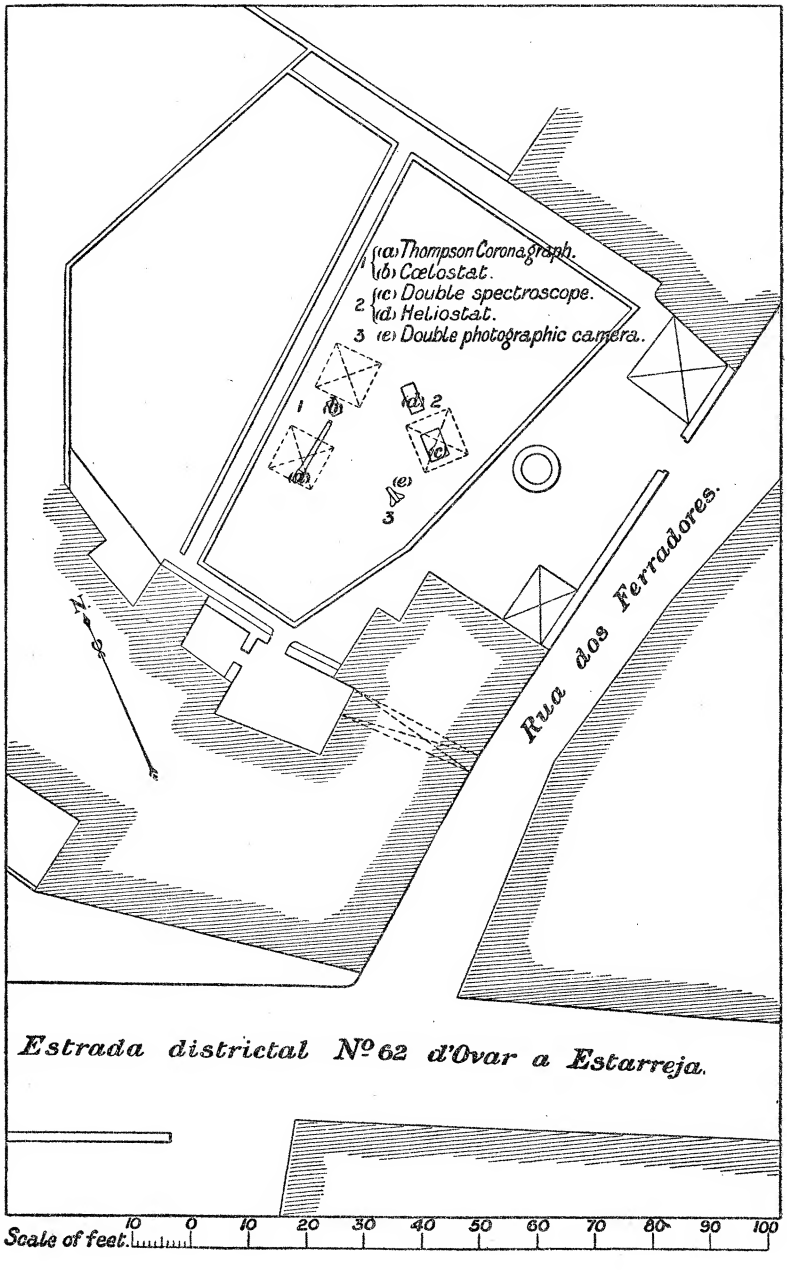
Ovar is a town about twenty miles south of Oporto, on the railway line to Lisbon; it is situated on a sandy plain, which stretches to the sea, the nearest point of the coast being about three miles distant. The meteorological conditions of this station proved to be good, the sky being clear on eight of the thirteen days during which the observers were there.

The station occupied by the observers was the garden of Mr. Silveiro's house; its position, taken from the Ordnance map in conjunction with plans of the town, furnished by the Public Works Department, is lat. 40° 51′ 30″ N., and long. 8° 37′ 3″ W., and is about $1\frac{3}{8}$ m. from the central line of the eclipse.

Erection and Disposition of Huts and Instruments.—It was found on arrival at the station that the loose sandy soil reached to a depth of at least 18 feet, thus rendering the erection of concrete or masonry piers unsuitable, as well as impracticable. The ground was accordingly cleared on May 17, the day of arrival, and thoroughly rammed; the wet weather which had prevailed previous to the arrival, rendered this the more effectual. On the same day the instruments and materials for the huts were brought from the railway station, half a mile away, in ox-waggons, and partially unpacked. The arrangement of instruments and huts was also roughly marked out.

On the next day, May 18, the huts to cover the instruments were erected, and boxes filled with stones, on which to mount them, were placed in position, The huts were light wooden frames, covered with Willesden waterproof canvas; they were fitted together at Greenwich before starting, and the woodwork marked, so that they were readily fixed up. There were three huts exactly alike structurally, each being 8 feet square and 8 feet high, rising to 10 feet at the gable; the canvas was thrown over the top and sides in two lengths, and tacked down to the woodwork; the ends of the huts were arranged with panels when necessary, which could be removed as required. Two of these huts, without any canvas at the adjacent ends, were bolted together, forming one large hut 16 feet by 8 feet, to cover the coronagraph and 16-inch cœlostat. For observation the bolts were removed, and the hut over the cœlostat moved back a few feet. The spectrographs were in the third hut, and the heliostat supplying them was outside the hut,

PLAN OF ECLIPSE STATION AT OVAR, 1900, MAY 28.



and provided with a light canvas cover when not in use. The equatorial with the double tube for the small-scale photographs of the corona was covered with a sheet of waterproof canvas when not in use. The arrangement of the different huts and instruments is shown in the accompanying plan.

The instruments were all erected on May 19, the observers thus having a clear week to adjust them, and to rehearse the observations.

Personnel.—The following list gives the names of those who took part in the observations :—

W. H. M. Christie :—Thompson coronagraph. Large scale photographs of corona.

F. W. Dyson :—Double photographic spectroscope. Spectrum of "flash" and of corona.

C. Davidson :—Double camera. Small scale photographs of corona to show extension.

J. J. Atkinson :—Assisted Mr. Dyson, moving plate-holders and changing plates for the flint prism spectroscope.

A. Berry :—Counted seconds for first half of totality, and then set the heliostat for second contact.

Mrs. Kennedy :—Counted seconds for second half of totality.

Frank Rawes :—Read thermometers during eclipse.

Four Portuguese Soldiers :—Handed plate-holders during totality for Mr. Christie and Mr. Davidson respectively.

The following was the method of procedure, which was carefully rehearsed on several occasions previously. The observers were stationed at their instruments, and Mr. Christie watched the diminishing crescent of the sun on the ground glass of his coronagraph. He had a paper scale on which the lengths of the crescent were marked, computed for the intervals 3 mins., 2 mins., 1 min., 45 secs., 30 secs., 25 secs., 20 secs., 15 secs., 10 secs., before totality ; at 15 secs. the length of the crescent was 2·64 inches, and at 10 secs. before totality 2·30 inches. Having previously given the signal, "Get Ready," Mr. Christie called out "Ten" at 10 secs. before totality, which was the signal to Mr. Dyson to begin the exposures for the "flash." At totality Mr. Christie again gave the signal (the monosyllable "Tup" was used) and Mr. Berry started a metronome which had been carefully rated to give seconds, and proceeded to count up to 50. Mrs. Kennedy took up the count at 51, and continued counting as far as 100, which had been estimated as 10 secs. beyond totality. While the count was proceeding, exposures at the several instruments were made, as described in the separate reports.

The Day of the Eclipse.—It was quite clear in the early morning, but some light cirrus clouds collected later, causing the observers some apprehensions. There was some light cloud in the sky during totality,

but there is no reason to suppose that it interfered seriously with the observations.

The first contact occurred at $2^h\ 6^m\ 20^s$ Lisbon Mean Time, and was observed by Mr. Christie on the ground glass of the coronagraph. The time of commencement of the total phase was not accurately noted; the duration was observed (by means of a stop-watch) and found to be $84\frac{1}{2}$ secs., during which the programme detailed below was carried out. After totality photographs were taken for orientation. The fourth contact was at $4^h\ 36^m\ 13^s$ Lisbon Mean Time. There was a good deal of light during totality, the diminution of light being similar to that occurring during a heavy thunderstorm in summer. The temperature fell about 8° during the eclipse.

During totality Mercury and Venus were seen, Mercury especially being very brilliant. The observers had not much opportunity of observing the attendant phenomena of the eclipse, and with the assistance which was kindly given them were only just able to provide adequately for the working of the instruments.

II. *Photographs of the Corona.*

The programme of observations was composed of two distinct parts:—

(1.) Photographs of the corona on a large scale to show structural detail.

(2.) Photographs on a smaller scale with rapid lenses to show the coronal streamers with the greatest possible extension.

(1) *Large-scale Photographs.*

(These were taken by Mr. W. H. M. Christie.)

The instrument used for (1) was the Thompson photographic telescope, with object-glass of 9 inches aperture and 8 feet 6 inches focal length, belonging to the Royal Observatory, in combination with a concave telephoto lens by Dallmeyer, of 4 inches aperture and 16 inches focus, fitted as a secondary magnifier, to give an image of the Sun 4 inches in diameter, with a field (for full pencils) of 14 inches diameter. The total length of the coronagraph was 12 feet—the equivalent focal length being about 36 feet. A cœlostat with 16-inch plane mirror (made by Dr. Common) was employed to reflect the rays into the coronagraph, which was mounted (on boxes filled with stones) so as to point to the mirror at an angle of depression of about 5°, and at an azimuth of about 56° West of South for the day of the eclipse. The camera was furnished with five plate-holders to take 15×15 inch plates, or for the shorter exposures 12×10 inch plates in a carrier.

The five slides for photographs of the corona during totality were

exposed as below, the exposures being given by the observer with the exposing shutter of the plate-holder, and the times noted by him, counting from the commencement of totality.

	Exposure.				
	Beginning.	End.	Duration.	Plate.	
No.					
1.....	7^s	8$\frac{1}{2}^s$	1$\frac{1}{2}^s$	Lantern	12 in. × 10 in.
2.....	16	22	6	Empress	12 „ × 10 „
3.....	30	50	20	Sandell's Triple-coated	15 „ × 15 „
4.....	56	68	12	Special Rapid	15 „ × 15 „
5.....	76	78$\frac{1}{2}$	2$\frac{1}{2}$	Lantern	12 „ × 10 „

As soon as possible after totality a second plate was put in No. 5 plate-holder, and exposed twice on the sun for orientation (with driving clock stopped for 3 min. between), the exposure being as short as possible ($\frac{1}{3}$ to $\frac{1}{2}$ sec.), and the aperture reduced to 2 inches.

"Abney squares" were put on Nos. 1, 3 (twice), and 5, after return home.

No. 1 ..... 300^s exposure at 5 ft. to standard candle.
No. 3 ... 5^s and 30 „ 5 „ „
No. 5 ..... 300 „ 3 „ „

The plates were all developed after return home, hydroquinone dilute being used. Nos. 1 and 5 unfortunately blistered badly in development, especially No. 1, though every care was taken, the developer being at a temperature of 60°. It is to be remarked that other plates developed at the same time under precisely similar conditions were free from blistering. No. 2 is to a certain extent disfigured with spots on the plate, which, however, do not materially interfere with the coronal detail.

No. 4 shows fine detail in the polar plumes and coronal streamers extending to nearly a diameter of the Sun from the limb. No. 3 shows nearly the same.

No. 5 shows very fine detail in the prominences in the S.W. quadrant, with gradation of brightness merging into the coronal structure close to the limb, thus showing a continuity between the two phenomena, and affording fresh evidence of the association between coronal streamers and prominences, which was indicated in the photographs of the 1898 eclipse.

It should be mentioned that the coronagraph was carefully focussed in the same manner as for the eclipses of 1896 and 1898,* by means of the image of an object (gauze net) in the plane of the plate reflected from the plane mirror of the cœlostat. The focus was thus obtained with great accuracy after two or three trials, and it was found that the field was remarkably flat.

* 'Monthly Notices R.A.S.,' vol. 57, p. 105; 'Roy. Soc. Proc.,' vol. 64, p. 8.

(2) *Small-scale Photographs to show Extension of the Corona.*

(These were taken by Mr. C. Davidson.)

The double camera, used in former eclipses, was adapted to carry a Dallmeyer rapid rectilinear lens of 4 inches aperture and 34 inches focus, working at f/8 in one-half of the tube. This lens was lent by the Royal Astronomical Society, the two halves, which had been used separately in former eclipses since 1882, having been reunited for the present eclipse.

In the other half of the camera tube there was mounted a new "Unar" lens by Ross, of 2·4 inches aperture and 12 inches focus, working at f/5.

Four plate-holders, each taking a pair of 16 × 16 cm. plates side by side were used during totality, both plates being exposed by a quarter turn of a shutter. A fifth plate-holder was used to obtain double images of the Sun for orientation as soon as practicable after totality.

The double camera was mounted on the equatorial stand of one of the Dallmeyer photo-heliographs, originally made for the Transit of Venus 1874, the middle section of the stand being removed to make it more handy.

Both lenses were carefully focussed on star-fields, the final adjustment being made by inserting thin metal rings beneath the flange of the lens.

The four slides for photographs of extension of the corona were exposed as below, the exposures being noted by the observer, counting from the commencement of totality.

	Exposure.			
No.	Beginning.	End.	Duration.	Plate.
1.....	3ˢ	8ˢ	5ˢ	Sandell Double-coated.
2.....	18	48	30	,, Triple-coated.
3.....	57	72	15	,, ,,
4.....	80	83	3	Empress.

Shortly after totality the fifth slide with Sandell double-coated plates was exposed three times on the Sun for orientation at intervals of $3\frac{1}{2}$ mins. with the driving clock stopped. In this case both lenses were stopped down to their smallest aperture, *i.e.*, f/64 for the "Unar" lens and f/44 for the Dallmeyer, and the exposure was as short as possible (about $\frac{1}{4}$ sec.).

"Abney squares" were put on Nos. 2 and 4 after return home.

No. 2 30 secs. exposure at 5 feet to standard candle.

No. 4 10 ,, ,, ,, ,,

The photographs with short exposure No. 4—3 secs. are the most

successful, and show the greatest extension, that taken with the "Abney" lens showing rays which can be traced on the east side to a distance of more than 2° from Sun's centre, and on the west side to a distance of fully $1\frac{3}{4}°$. This is further than they could be traced visually under the atmospheric conditions at Ovar, where the observers traced them to a distance estimated at $\frac{2}{3}$ of distance of Mercury from centre, *i.e.*, $1\frac{1}{3}°$.

III. *The Spectroscopic Cameras.*

(By F. W. Dyson.)

Instruments.—The spectroscopes used were two kindly lent by Captain Hills, and employed by him in the Indian Eclipse of 1898, January 22. The details of their adjustments as used at Ovar are as follows:—

	Spectroscope No. 1.	Spectroscope No. 2.
Objective	Cooke, achromatic, $4\frac{1}{2}$ in. aperture, 6 ft. $2\frac{1}{4}$ in. focus.	Single quartz lens, 5 in. aperture, 4 ft. $7\frac{3}{4}$ in. focus.
Collimator and camera lens	Single quartz lens, $2\frac{1}{2}$ in. aperture, 30 in. focus.	Single quartz lens, 3 in. aperture, 36 in. focus.
Slit	$1\frac{1}{2}$ in. by 0·0014 in.	2 in. by 0·0012 in.
Prisms	Two dense flint prisms of 60°, $4\frac{1}{2}$ in. base, $2\frac{1}{2}$ in. height.	Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), $3\frac{1}{2}$ in. base, $2\frac{3}{4}$ in. height.
Prisms at minimum deviation for	H_γ (λ 4340).	H_ζ (λ 3889).

The width of the slits were adjusted by a method given by Mr. Newall. The third diffraction image of the slit, viewed by putting the eye near the position of the plate, was made to come on the edge of the object-glass by altering the width of the slit, and the slit left at this reading.

The length of the spectrum on the plate for spectroscope No. 1 was $3\frac{1}{4}$ inches from H_β (λ 4861) to K (λ 3934), and for spectroscope No. 2 $2\frac{1}{4}$ inches from λ 4100 to λ 3500.

Both spectroscopes were mounted horizontally, and were supplied with light by a heliostat furnished with a 12-inch flat mirror.

Erection and Adjustment of Instruments.—As the nature of the ground was unsuitable for brickwork or concrete piers, three of the boxes in which the instruments were carried were filled with stones and the

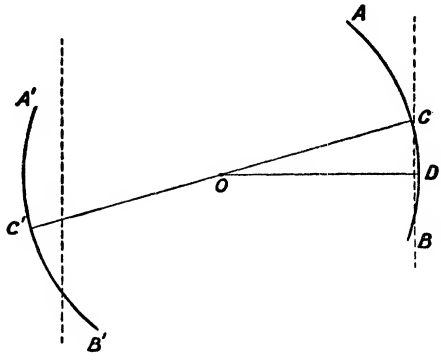
instruments erected on them. On one of these—a large clock case, 5 feet long, $2\frac{1}{2}$ feet broad, and $1\frac{1}{2}$ feet high—the heliostat was placed, a light wooden frame holding the two objectives. This was covered when not in use by Willesden canvas on a light wooden framework which could be readily lifted on and off. The spectroscopes stood on a mahogany table, 5 feet by 4 feet, which rested on the topmost of two boxes. The boxes were of such a height that the middle of the slits of the two spectroscopes were respectively half an inch below and half an inch above the centre of the mirror. This had to be arranged somewhat carefully, as a 5-inch and a $4\frac{1}{2}$-inch lens had to be supplied with light by a 12-inch mirror whose normal at the time of the eclipse was inclined more than 40° to the incident and reflected rays. The spectroscopes were in a hut, 8 feet square, made of Willesden canvas, facing north and south, and with the north side open when the instruments were in use.

The adjustment of the polar axis of the heliostat was made by means of an attached theodolite, the altitude of the axis being first set to the latitude, and the azimuth then adjusted by observing the sun's declination at different hour-angles from 9^h to 16^h. In this way the instrument was readily adjusted till the observed declinations of the sun agreed to within 2′ with those of the Nautical Almanac throughout the above range of hour-angle. The stability of the mounting of the instrument on the sand was quite satisfactory, only very small changes in level occurring, and no perceptible changes in azimuth. The only difficulty experienced with the heliostat was in the driving, which is not very satisfactory at large azimuths.

Programme of Exposures.—The two spectroscopes were adjusted to be as nearly as possible on the sun's limb simultaneously, and the programme of exposures was the same for both. The cameras of the two spectroscopes were provided with rack movements, so that a number of exposures could be made on the same plate. A flap was arranged so that the exposures for both spectroscopes were made at the same time. The programme, as arranged with an expected duration of totality of 90 secs., was as follows :—

Ten exposures were made of 1 sec. duration beginning 10 secs. before totality at about 1 sec. apart for the spectrum of the "flash" at the beginning of totality. The plates were then changed, and at 20 secs. from the beginning of totality the plates were exposed for 50 secs., *i.e.*, till 70 secs. from the beginning of totality for the spectrum of the corona. The plates were again changed and the image on the slit moved by Mr. Berry by means of the slow motion of the heliostat, and ten exposures of 1 sec. duration, beginning at 80 secs. after first contact, were given for the spectrum of the "flash" at second contact. The conditions under which the "flash" was photographed, as determined by the circumstances of the eclipse at Ovar and

the instruments used, are shown in the accompanying diagram, which is enlarged about four times.



O is the centre of the sun's disc; AB is the bright arc as seen 10 secs. before totality, and is 70°. The centre of the arc, C, which is about 1° from the equator, is 16° above the point D where the arc is vertical and could be made to touch the slit. The slit, which is represented by dotted lines, cut the bright arc between C and D, the horizontal distance between C and D being $\frac{1}{50}$th of an inch. The time for the first exposure, viz., 10 secs. before totality, was given to the observers by the Astronomer Royal from the length of the rapidly diminishing arc as seen by him on the ground glass of the coronograph. This time appears to have been given correct to about 1 sec.

The position of the image on the slit was not changed for the spectrum of the corona, which was obtained near the point of second contact.

For the "flash" at third contact the slow motion of the heliostat was used, making the sun's image travel in the direction OC of the diagram, the amount of the displacement being determined by watching the sun in the attached theodolite. The position of the slit relatively to the bright arc is shown in the second diagram; in this case the slit was not nearly tangential to the sun's limb.

The photographic plates used were Ilford "Empress" for the first "flash" photograph with the flint spectroscope and for both the "flash" photographs with the quartz. An Ilford "Ordinary" was used for the second "flash" photograph with the flint. Cadett "Lightning plates" were used for both photographs of the corona spectrum.

Spectrum of the Sun's Limb.—The series of spectra of the limb show a large number of lines, but they have not yet been examined in detail. With the flint spectroscope, a spectrum is obtained extending from F to K. This is good from F to *h*. With the quartz the spectrum reaches from *h* to λ 3300, and is in good definition to about λ 3450. The photographs taken with the quartz spectroscope at the

beginning of totality are an interesting series. They show a long series of hydrogen lines (26 beginning at *h*), and a large number of iron and titanium lines. The difference in behaviour of these two metals is shown in a striking manner, the titanium lines, like the hydrogen lines, being bright in the whole series of photos. beginning 10 secs. before totality, while the iron lines are reversed in the earlier photographs. Titanium lines at wave-lengths 3685·30, 3761·46, and 3759·42 are specially bright. A reproduction is given of part of this series of photographs. (Plate 23).

The Corona Spectra.—Reproductions of these spectra are given in the accompanying plate (Plate 24). With the flint spectroscope a continuous spectrum is obtained from F to H. Eight bright lines are distinctly shown stretching right across the continuous spectrum, and several shorter lines in the densest part. The line 1474 K is not shown, probably because plates specially sensitive in the green were not used. The wave-lengths of the lines have not yet been determined. The positions of the corona lines are indicated on the plate and can be seen in the top band, though only faintly.

With the quartz spectroscope a continuous spectrum is shown which can be faintly traced as far as λ 3600. Strong bright lines are shown at λ 3987 and λ 3801.

November 22, 1900.

The LORD LISTER, F.R.C.S., D.C.L., President, in the Chair.

Mr. John Horne was admitted into the Society.

A List of the Presents received was laid on the table, and thanks ordered for them.

His Grace the Duke of Northumberland, a member of Her Majesty's Most Honourable Privy Council, was balloted for and elected a Fellow of the Society.

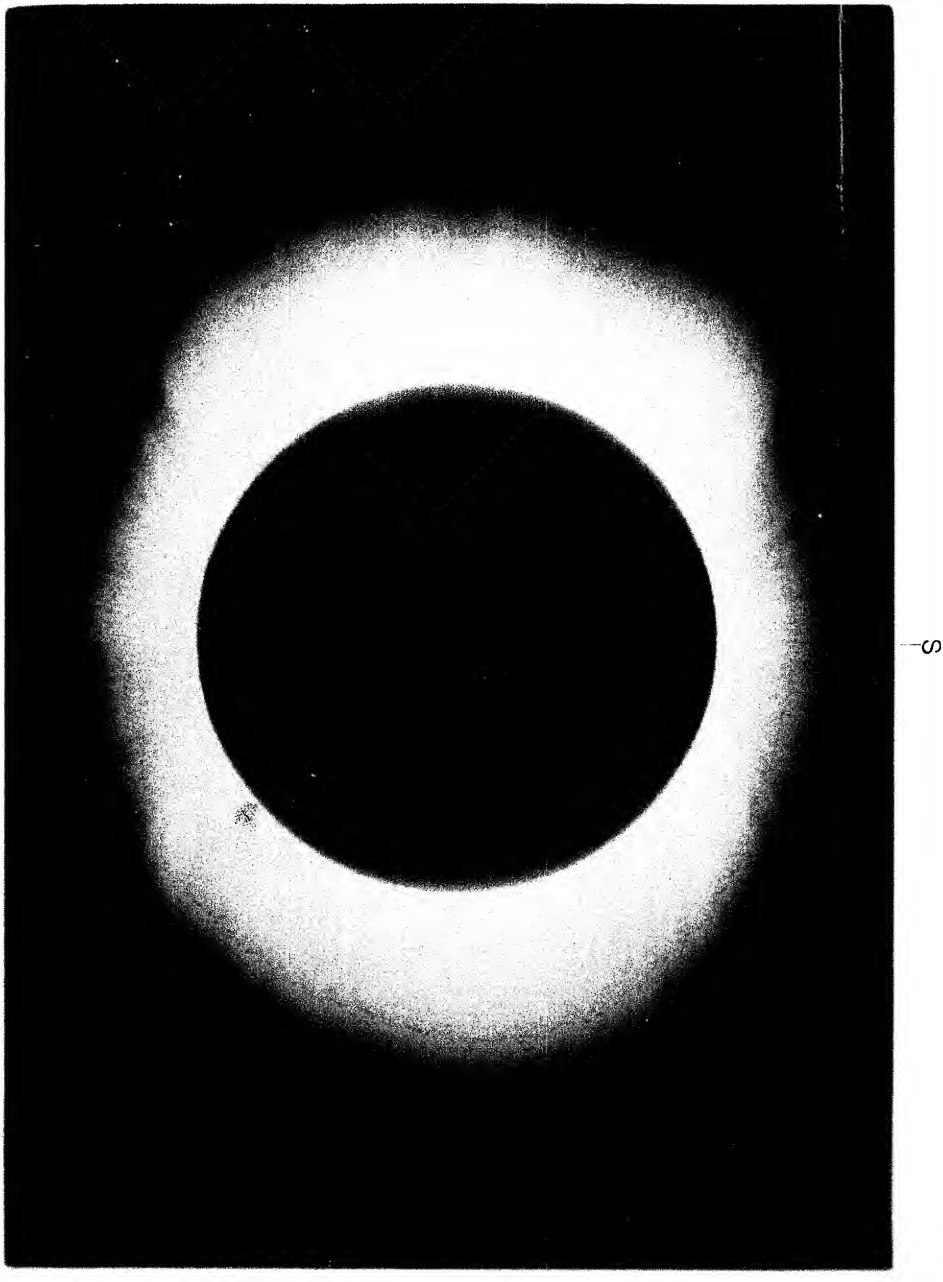
In pursuance of the Statutes, notice of the ensuing Anniversary Meeting was given from the Chair, and the list of Officers and Council nominated for election was read as follows:—

President.—Sir William Huggins, K.C.B., D.C.L., LL.D

Treasurer.—Alfred Bray Kempe, M.A.

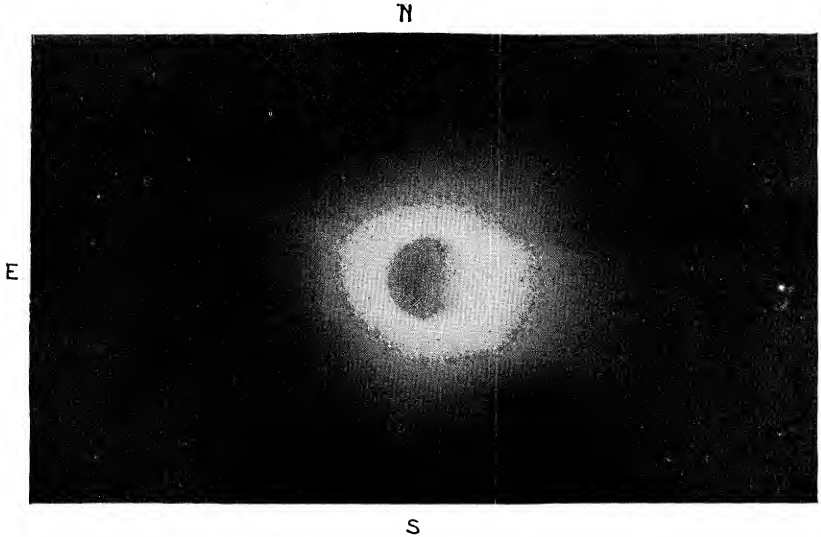
THE SOLAR CORONA.

1900. MAY 28TH.

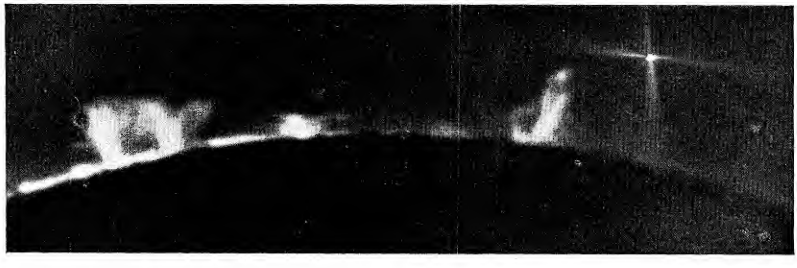


Reduced to $\frac{3}{10}$ size from Photograph No. 4, taken at Ovar, Portugal, by W. H. M. Christie. Exposure 12secs. Thompson Coronagraph. Aperture 9in. Equivalent focus 36 feet.

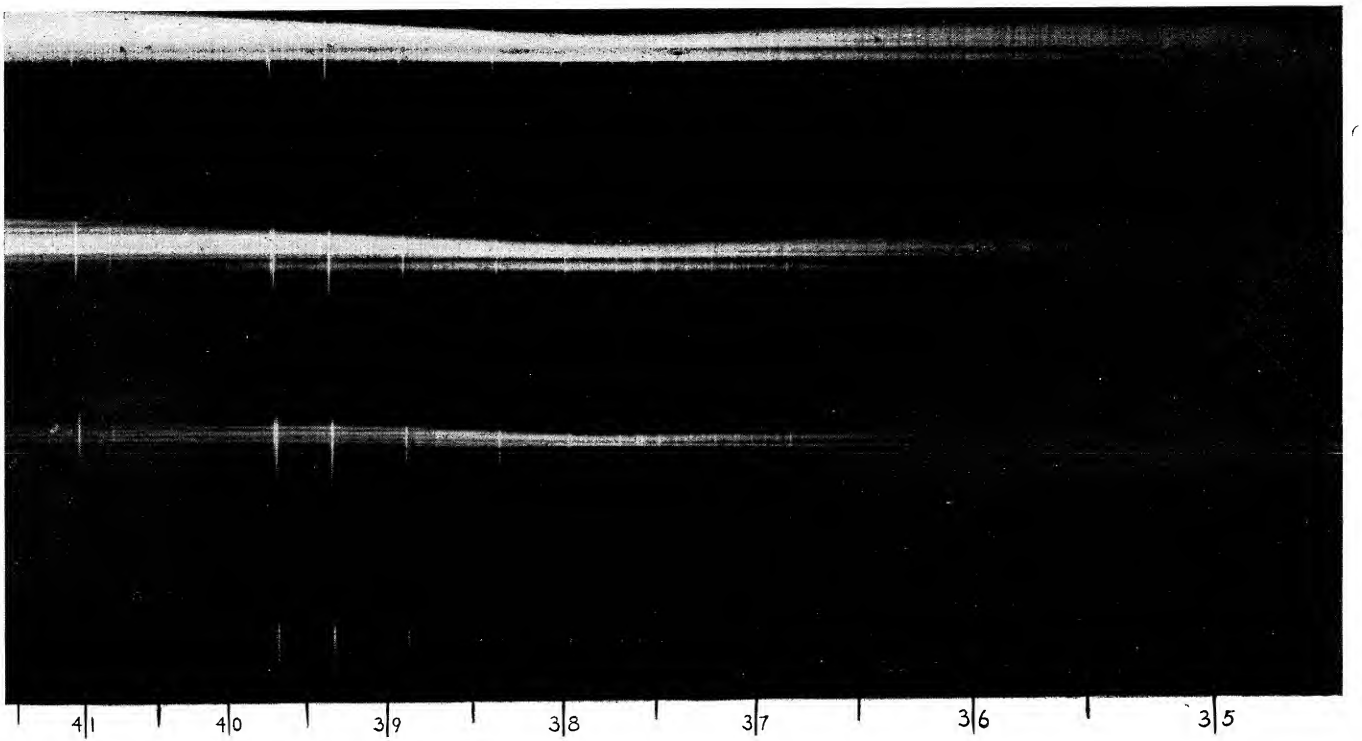
ECLIPSE OF SUN. OVAR. 1900, MAY 28.



Photograph of Corona, obtained with Dallmeyer rapid rectilinear lens of 4 inches aperture (enlarged 1½ times from photograph No. 1). [The planet Mercury is shown on the western side of the photograph.]

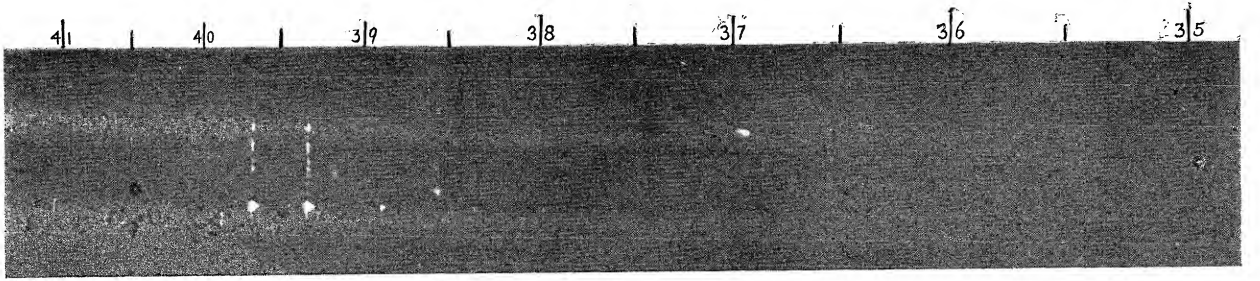


Photograph of Prominences in S.W. Quadrant (enlarged 2½ times from photograph No. 5, taken with the large coronagraph). [The spot with cross rays on the right-hand side is a defect in the photographic plate.]

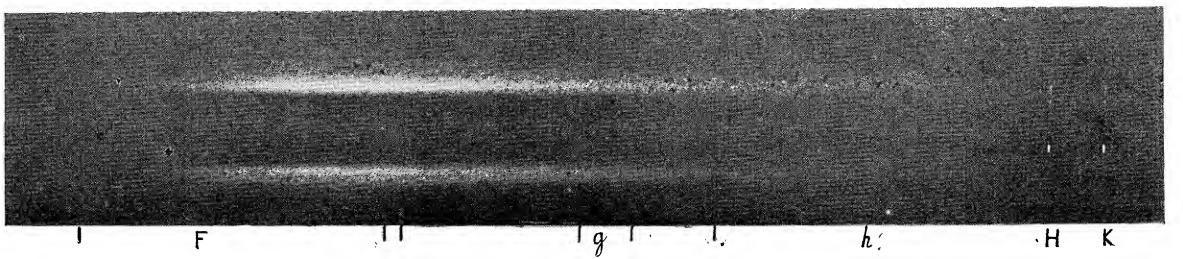


Series of Spectra of Sun's Limb, obtained with Quartz Spectroscope, near the beginning of totality (enlarged $2\frac{3}{4}$ times).
(Approx. 5^s, 3^s, 1^s before totality, and 1^s after.)

ECLIPSE OF SUN. OVAR. 1900, MAY 28.



Spectrum of Corona, taken with the Quartz Spectroscope (enlarged $2\frac{3}{4}$ times).



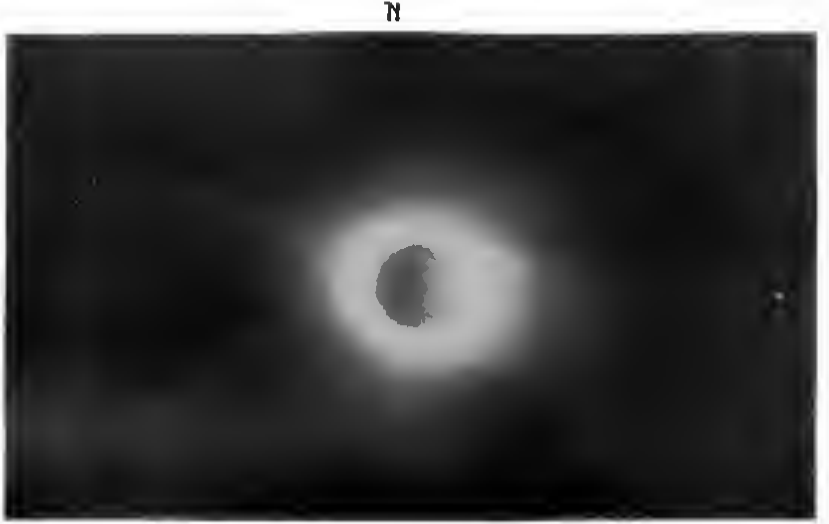
Spectrum of Corona, obtained with Flint Spectroscope (enlarged $1\frac{1}{2}$ times).

THE SOLAR CORONA.

1900. MAY 28TH.

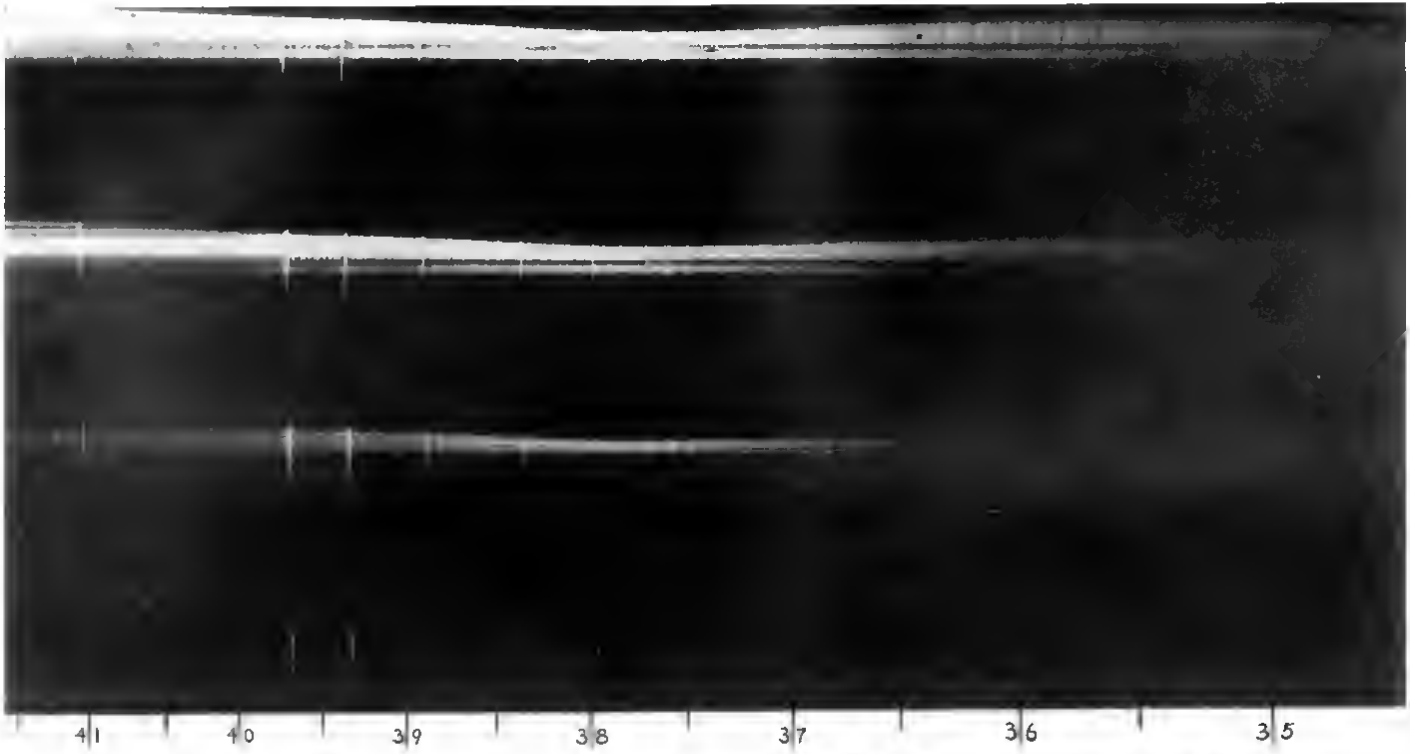
Reduced to ⅓ size from Photograph No. 4, taken at Ovar, Portugal, by W. H. M. Christie. Exposure 12secs. Thompson Coronagraph. Aperture 9in. Equivalent focus 36 feet.

ECLIPSE OF SUN. OVAR. 1900, MAY 28.



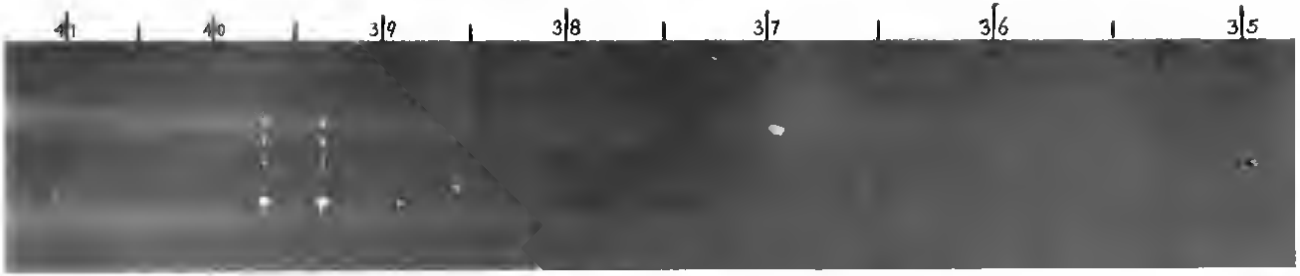
Photograph of Corona, obtained with Dallmeyer rapid rectilinear lens of 4 inches aperture (enlarged 1½ times from photograph No. 1). [The planet Mercury is shown on the western side of the photograph.]

Photograph of Prominences in S.W. Quadrant (enlarged 2½ times from photograph No. 5, taken with the large coronagraph). [The spot with cross rays on the right-hand side is a defect in the photographic plate.]

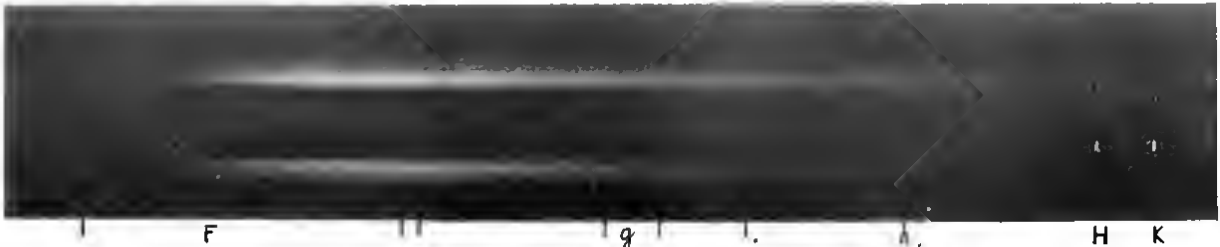


Series of Spectra of Sun's Limb, obtained with Quartz Spectroscope, near the beginning of totality (enlarged 2¾ times).
(Approx 5ˢ, 3ˢ, 1ˢ before totality, and 1ˢ after.)

ECLIPSE OF SUN. OVAR. 1900, MAY 28.



Spectrum of Corona, taken with the Quartz Spectroscope (enlarged 2½ times).



Spectrum of Corona, obtained with Flint Spectroscope (enlarged 1½ times).